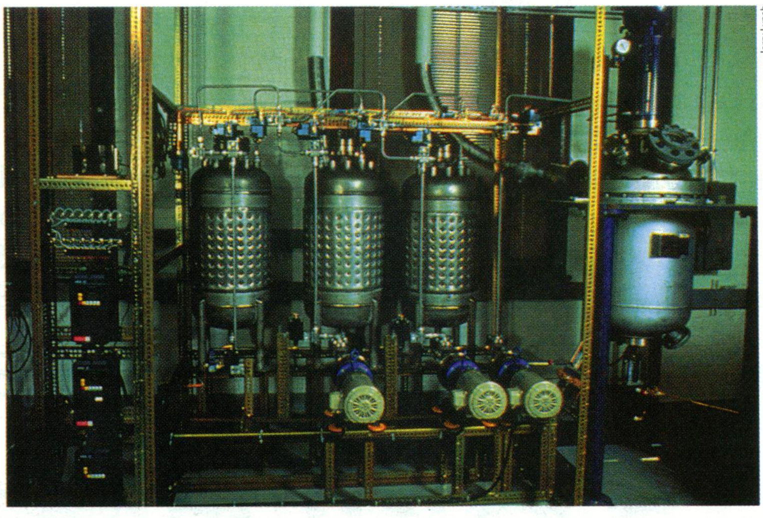
# DisSOLVING THE PLASTICS PROBLEM

As plastics play an increasing role in packaging and consumer products, they also take up a growing percentage of municipal solid waste streams and pose environmental challenges. Once in the waste stream, the plastics are dealt with in one of three ways: incineration, burial, or recycling. Recycling—the least practiced of the three—may benefit from a new technology that promises to make it a more economically attractive alternative.

Incineration is used to dispose of over 16% of all municipal wastes. More than two-thirds of the incinerators in the United States burn garbage in waste-to-energy facilities that use heat energy to generate steam or electricity. Because plastics are typically derived from petroleum or natural gas, they can generate almost as much energy as fuel oil, although the much higher amount of energy initially required to produce the plastic is lost. Potential hazardous emissions from incinerating plastics include hydrogen chloride, dioxin, cadmium, and fine particulate matter. Even with recent, stricter air pollution standards there is considerable public opposition to incineration.

Landfilling plastics is generally a benign practice because plastics are chemically inert. Some additives to plastics do provoke concern if they should migrate from the plastics into the leachate. For example, heat stabilizers are toxic, but their stability depends in part on the types of plastics and heat stabilizers in use. Heavy metals are being phased out of packaging materials and are a diminishing problem. Plasticizers known as phthalates are hazardous substances and have been found in a number of leachate analyses at various concentrations. A complicating factor in analyzing the leachate is the frequent use of plastic components in leachate collection and groundwater monitoring systems—these components themselves may contribute some of the additives.

A more significant problem for landfilling is that plastic wastes now constitute about 10% by weight and about 20% by volume of the municipal waste stream. Since plastics are essentially nondegradable, their volume will not shrink and plastics may eventually consume a disproportionate amount of landfill space. The EPA, in its report *Characterization of Municipal Solid Wastes*, says that plastics comprised an estimated 400,000 tons of municipal solid waste in 1960. By 1994, that figure was 19.8 million tons. The American Plastics Council reports that only 4.7% of this total was recovered, although recovery of some plastic containers has increased substantially. Polyethylene terephthalate (PET) soft drink bottles and their base cups are recovered at a rate of 50%. High-density polyethylene (HDPE) milk and water bottles are recovered at a rate of about 30%. The other common plastics in the waste stream are polystyrene (PS),



Jerry Lynch

**Super sorter.** The pilot-scale selective dissolution system at Renssalaer Polytechnic Institute was designed to eliminate manual sorting of plastics for recycling.

low-density polyethylene (LDPE), polypropylene (PP), and polyvinyl chloride (PVC).

Recycling is a four-part exercise of collecting a mix of plastics at curbside or dropoff centers, sorting the plastics into the six types, reclaiming the plastic by physically or chemically converting them to flakes or pellets, and then processing the flakes or pellets into a final product. One reason plastics are recycled less often than glass or metal is because the sorting step is very labor-intensive and, hence, expensive. However, the cost and accuracy of sorting are crucial elements in making plastics recycling economically viable because each type of plastic has different performance characteristics that make it best suited for specific applications.

## Getting into the Process

"Plastics recycling is a tough business," says Jerry Lynch, who manages a project at Rensselaer Polytechnic Institute designed to eliminate the sorting step and reclaim the plastics. "Plastics are contaminated and not easy to wash. They come in different colors and materials, even within one classification. And collection is difficult, meaning that plastics take up a lot of room, and [they] are light and unbreakable, so transportation is expensive. Finally, virgin plastic is inexpensive."

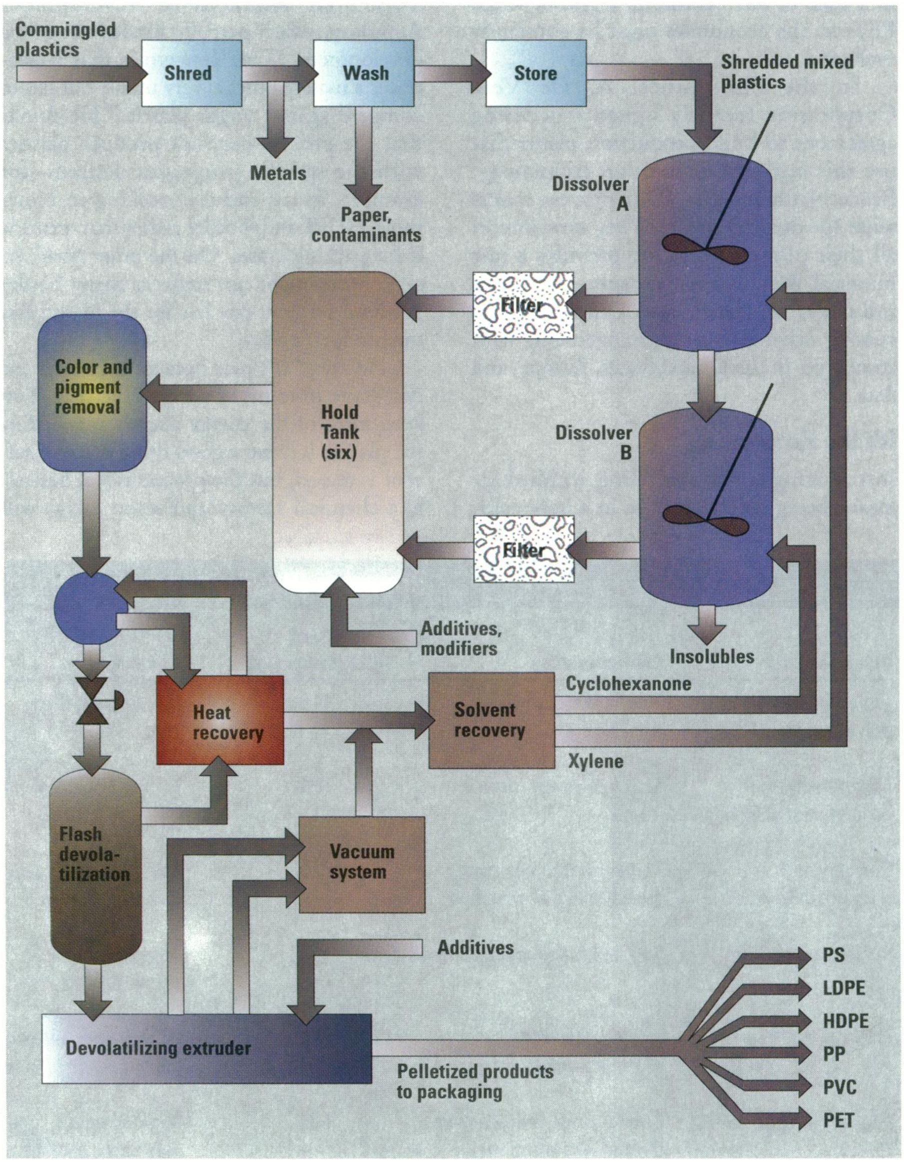
The Rensselaer technology eliminates sorting by introducing a selective dissolution process first developed by Lynch and chemical engineering professor Bruce Nauman. They developed this technology eight years ago by combining their expertise—Nauman's in improving the physical properties of polymers and Lynch's in chemical industry processes.

Through a series of processing steps, the unsorted (or commingled) plastics are shredded, washed, and then selectively dissolved in a common solvent. Since each type of plastic dissolves at a different temperature, it is possible to dissolve and remove them from the mixture one type at a time. Alternative new technologies for addressing commingled plastics are depolymerization (an energy-intensive way of breaking polymers into their constituent monomers) and blending (which makes new materials by mixing plastic types but does not yet meet consumer quality standards).

"In a typical process run on our pilot system, we use unsorted plastic pieces shredded into 3/4-inch pieces," says Lynch. "They get washed to remove impurities, but any remaining contaminants won't cause problems and will be removed later in the process." After drying, the pieces are fed into a mixing vessel along with a xylene solvent at room temperature (15°C). "This is the heart of the process," Lynch continues. "At this temperature, polystyrene dissolves upon contact with the solvent and forms a solution of about 6% PS by weight." The polystyrene solution is drained from the mixing vessel through filters to a holding tank, leaving behind the five undissolved plastics. The process is repeated to flush out any remaining polystyrene.

In the next round, hotter xylene is added. "We mix the remaining commingled plastics in xylene at 75°C," says Lynch. "This causes all the low-density polyethylene to dissolve. The low-density polyethylene solution is drained and the cycle gets repeated with increasing xylene temperatures for high-density polyethylene and polypropylene. When only polyvinyl chloride and polyethylene terephthalate are left, we transfer them to a smaller vessel for better mixing and add a xylene/cyclohexanone solvent." The PVC dissolves out first at 120°C and, finally, the PET dissolves at 180°C. The polymer solutions are stored in six holding tanks from which each is moved to a flash devolatilization vessel and a devolatilizing extruder where the polymer is separated from the solvent. All solvent is reused in the process and any impurities are collected for use as fuel, as are any low molecular weight vapors released by the polymers, such as hexane and hexene. The pure polymer is made into pellets and packaged for use.

Lynch says that selective dissolution also works with the plastics in durable goods such as carpets, consumer electronics, and automobile components. Reclaiming these plastics has been complicated in the past. He notes, "We've worked with Toyota to recycle dashboards. The plastics used in these



Jerry Lynch

**Pick and choose.** In a series of steps within a closed system, commingled plastics are shredded, selectively dissolved, collected, and processed into polymer pellets for reuse.

applications are often combined with something else like a metal part in such a way that you cannot mechanically separate or rework them. The point is, we can tailor the process to fit each situation." In the case of many durable goods, the value of the reclaimed plastics is much higher than that of PET.

"It's basically a plastics manufacturing plant but smaller and cleaner," concludes Lynch. "Conceptually it looks like an oil refinery and it's meant to be built where such facilities are sited." In fact, a preliminary design for a 70 million pound per year commercial plant has been drawn. The capital costs were estimated to be about $33 million, with a profit-making selling price for the recycled plastics of about $0.25 per pound—below the current range of many virgin plastics on the market. However, market conditions in the United States are in a state of flux because of a glut of virgin PET, so the economics must be constantly evaluated.

In the Philippines, A. De Vera Corporation recently signed a licensing agreement to build production plants that use this selective dissolution technology. Bruce Nauman says, "Our process makes sense for the Philippines. They now import all their plastic. Recycling provides a raw material they can use to start their own industry." Nauman and Lynch are discussing other licensing arrangements with companies in the United States, Europe, and Asia.

### It's the Economics

Introducing a new recycling technology means being able to survive in a very competitive industry. "It's a wonderful process," according to Joseph Visalli, the project manager for environmental research at the New York State Research & Development Authority, which partially funded the initial development. "One concern is that it produces a material that is very usable but has to compete against virgin plastic." He thinks that the process may not produce plastics with the specific properties desired—for example, by an end-user seeking to blow-mold HDPE into bottles rather than extrude it for packing crates. On the other hand, he says, "You might not make as many bottles per hour but you pay less for the plastic and the product is okay."

He says, "It's nice because this takes the best route in terms of energy efficiency. You keep most of the energy already invested in the plastic. It's also a good thing that the solvent is reused, but the process is still basically a chemical factory and some toxins will escape. It's very capital intensive and as you get closer to no [toxic] releases you spend more money." As Visalli and others who follow recycling note, plastic manufacturers may not be enthusiastic about this technology since their investment is already made in virgin plastic processing facilities.

The economics of the process is also a question for Cornell University professor of chemical engineering Ferdinand Rodriguez, who has researched solvent dissolution technologies for many years. Echoing Lynch's statement, Rodriguez says, "Recycling is a tough business." He stresses that "Rensselaer's technology is probably one of the most advanced and realistic. But you need to do it on a large scale because economics are a big issue. Recycling is a matter of scale and of educating the public to its importance."

**Conard Holton**

### Suggested Reading


Battle KE, Moore AP, Lynch JC, Nauman EB. Plastics recycling by selective dissolution. Presented at the 1992 Petrochemical Review, 26 March 1992, Houston, TX.

The League of Women Voters. The Plastic Waste Primer: A Handbook for Citizens. New York:Lyons & Burford, 1993.

Matsuda M, Asada S, Webber K, Lynch JC, Nauman EB. Application of selective dissolution to the recycling of commingled automotive plastics. Presented at the Society of Automotive Engineers meeting, February 1994, Detroit, MI.

U.S. EPA. Characterization of Municipal Solid Waste in the United States: 1995 Update. EPA 530-R-96-001. Washington, DC:U.S. Environmental Protection Agency, 1995.


### Common Plastics and Their Uses

| Polymer Resin | Characteristics | % of All Plastics (1991) | Common Uses | Products Made from Recycled Resins |
|---|---|---|---|---|
| High-density polyethylene (HDPE) | Tough, flexible, translucent | 14.6 | Beverage bottles, pipe, cable, film | Motor oil bottles, detergent bottles, pails |
| Low-density polyethylene (LDPE) | Moisture-proof, inert | 18.3 | Trash bags, coatings, plastic bottles | Trash bags, pallets |
| Polyethylene terephthalate (PET) | Tough, shatter-resistant, gas permeation-resistant | 2.3 | Soft drink, detergent, and drink bottles | Carpets, fiberfill, non-food bottles, containers |
| Polypropylene (PP) | Stiff, heat- and chemical-resistant | 13.2 | Auto battery cases, screw-on caps, food tubs, film | Auto parts, batteries, carpets |
| Polystyrene (PS) | Brittle, clear, rigid, good thermal properties | 7.8 | Housewares, electronics, fast food packaging, food utensils | Insulation board, office equipment, reusable cafeteria trays |
| Polyvinyl chloride (PVC) | Strong, clear, brittle unless treated with plasticizer | 14.5 | Sporting goods, luggage, pipes, auto parts, miscellaneous packaging | Drainage pipes, fencing, house siding |

Source: The League of Women Voters. The Plastic Waste Primer: A Handbook for Citizens. New York: Lyons & Burford, 1993.